34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
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MBSE for Manufacturing

Securing Strategic Alignment and Producibility of a new Program from the Outset!

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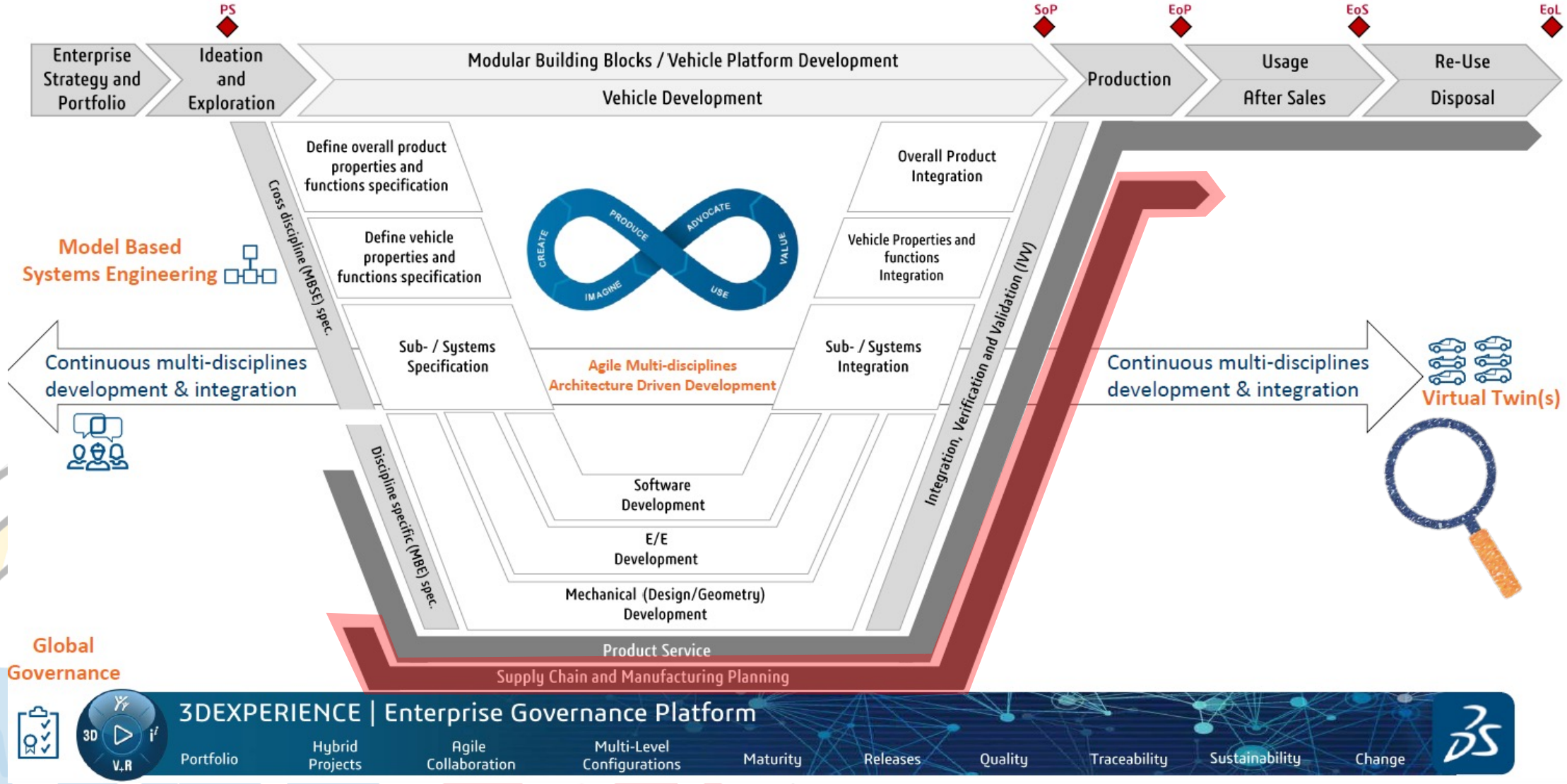
what if we shifted our focus?



Challenges in developing Cyber Physical Systems

Challenges

- From isolated products to interconnected systems of systems
- Budgetary constraints demand predictability in delivery and informed decision-making
- Certification Complexities arising from rapidly emerging new technologies
- Integrating new innovative technologies into existing systems
- Discontinuities throughout the supply chain

Challenges on Industrial systems by launching a new program

Challenges

- **Adapting Production Facilities**
- **Supply Chain Integrity & Resilience**
- **Risk of strategic misalignment**
- **Investment Justification Risk**
- **Technology Integration and Modernization**

Real-World Example

outsourcing significant portions of the Dreamliner's production to global suppliers…

… underestimation of the complexities and challenges associated managing a global supply chain

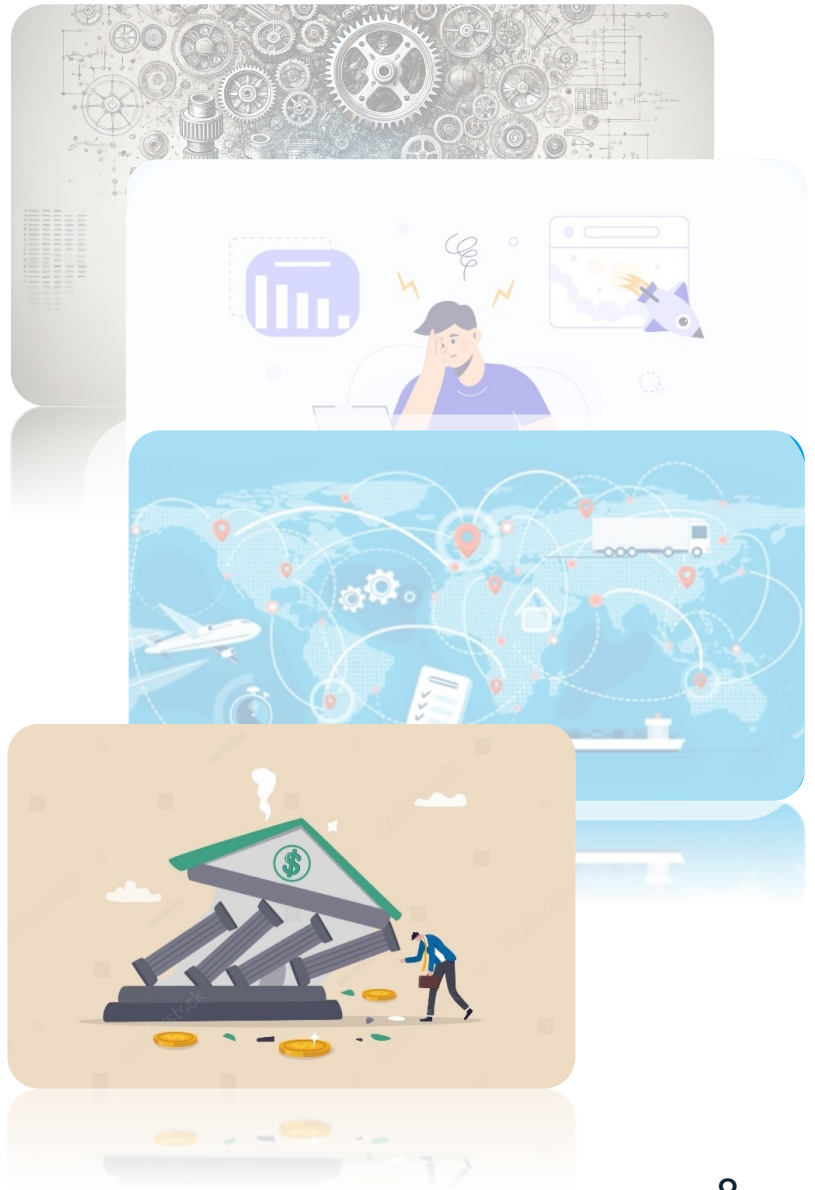
… without fully considering the high-level requirements and the complexities of managing a vast, global supply chain

… led to significant delays and cost overruns, undermining the initial cost efficiency and production rate objectives

… Issues such as supply chain disruptions and design flaws were only identified after significant resources had already been invested

What should be changed?

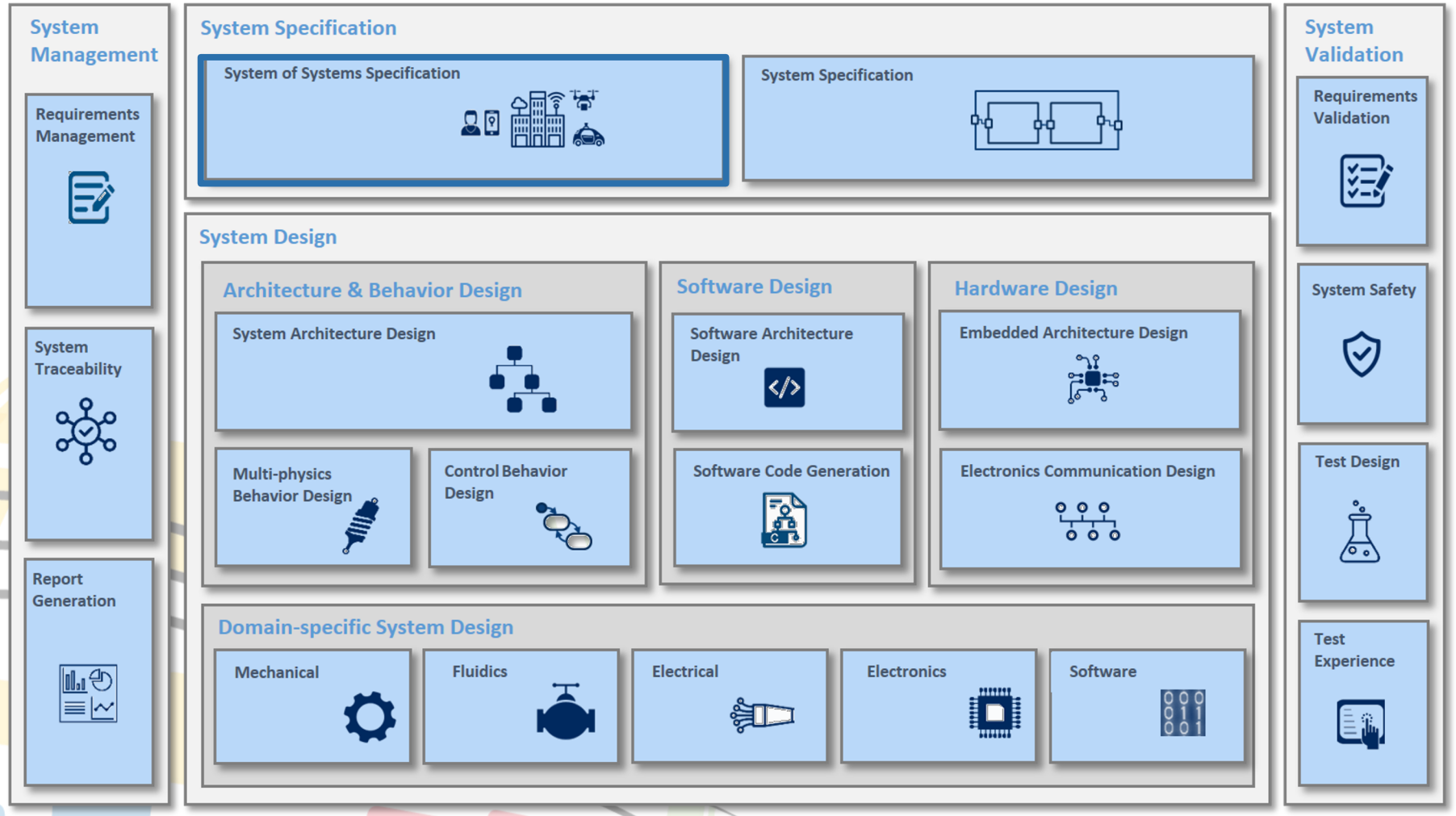
- **Premature Focus on Solution Implementation**
- **Inadequate Integration of High-Level Requirements**
- **Late Assessment of suitability of existing Supply Chain**
- **Late Discovery of Misalignment with Strategic Goals**



Early stage Modeling & simulation possibilities to:

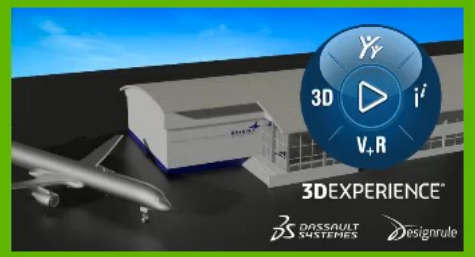
- **Integrate strategy Level from the beginning (Systems of Systems Level)**
- **Assess the existing supply chain and production facilities**
- **Early performance validation of changes/updates to the facilities at plant level**
- **Set precise requirements for each supplier at an early stage**
- **Perform early Stage Process Configuration Optimization**

Integrate strategy Level from the beginning



Air Transportation System

OEM Organization System



Legend

- Enterprise
- Product
- Manufacturing

Glue Model Tier1

uses

uses

uses

N102 Aircraft System

N102 Industrial Network System

Integrating Organizational Level from the beginning...

What Did We See?

Capturing Enterprise goals, drivers and challenges

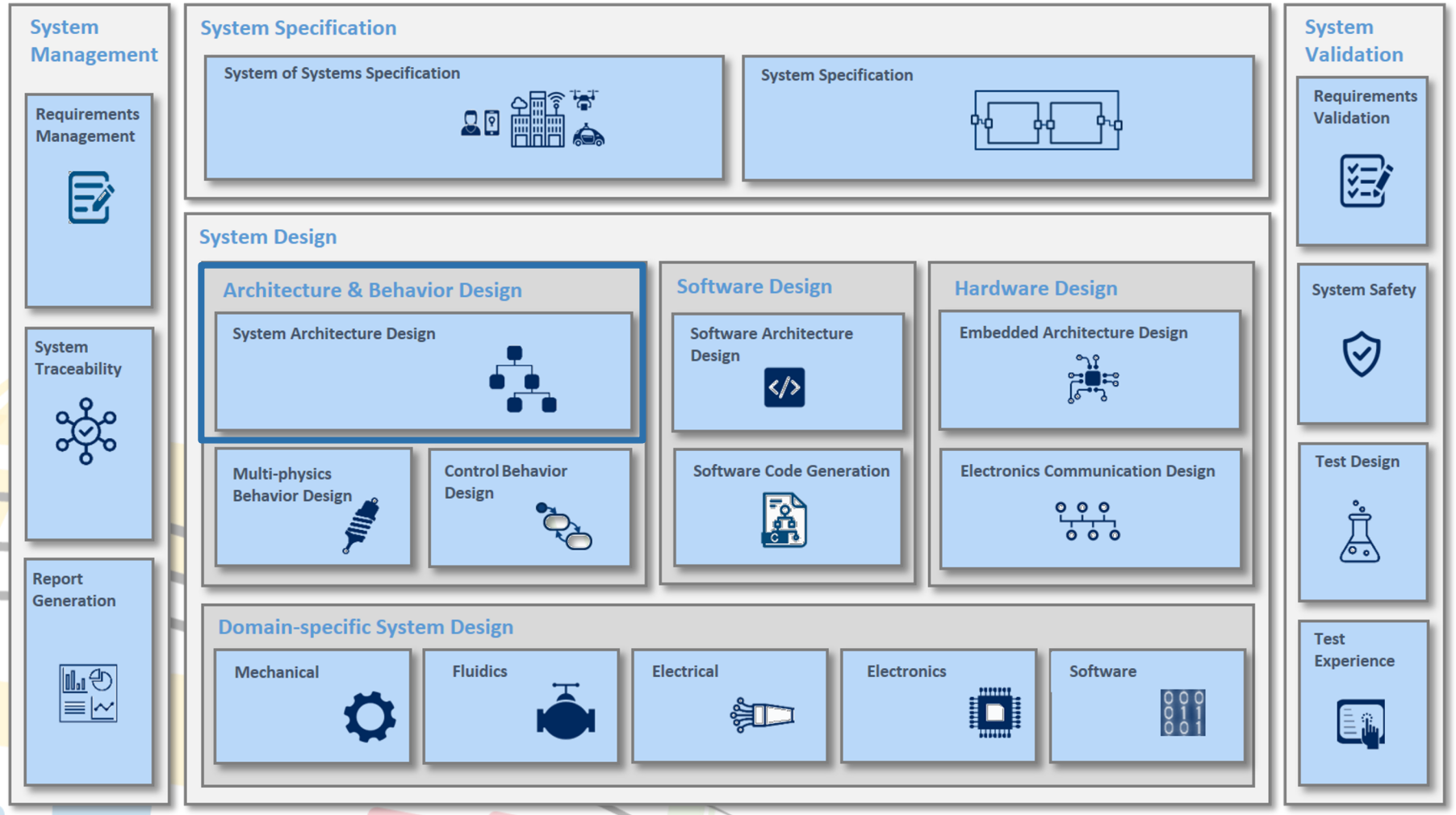
Refining Strategic Goals into Specific KPIs

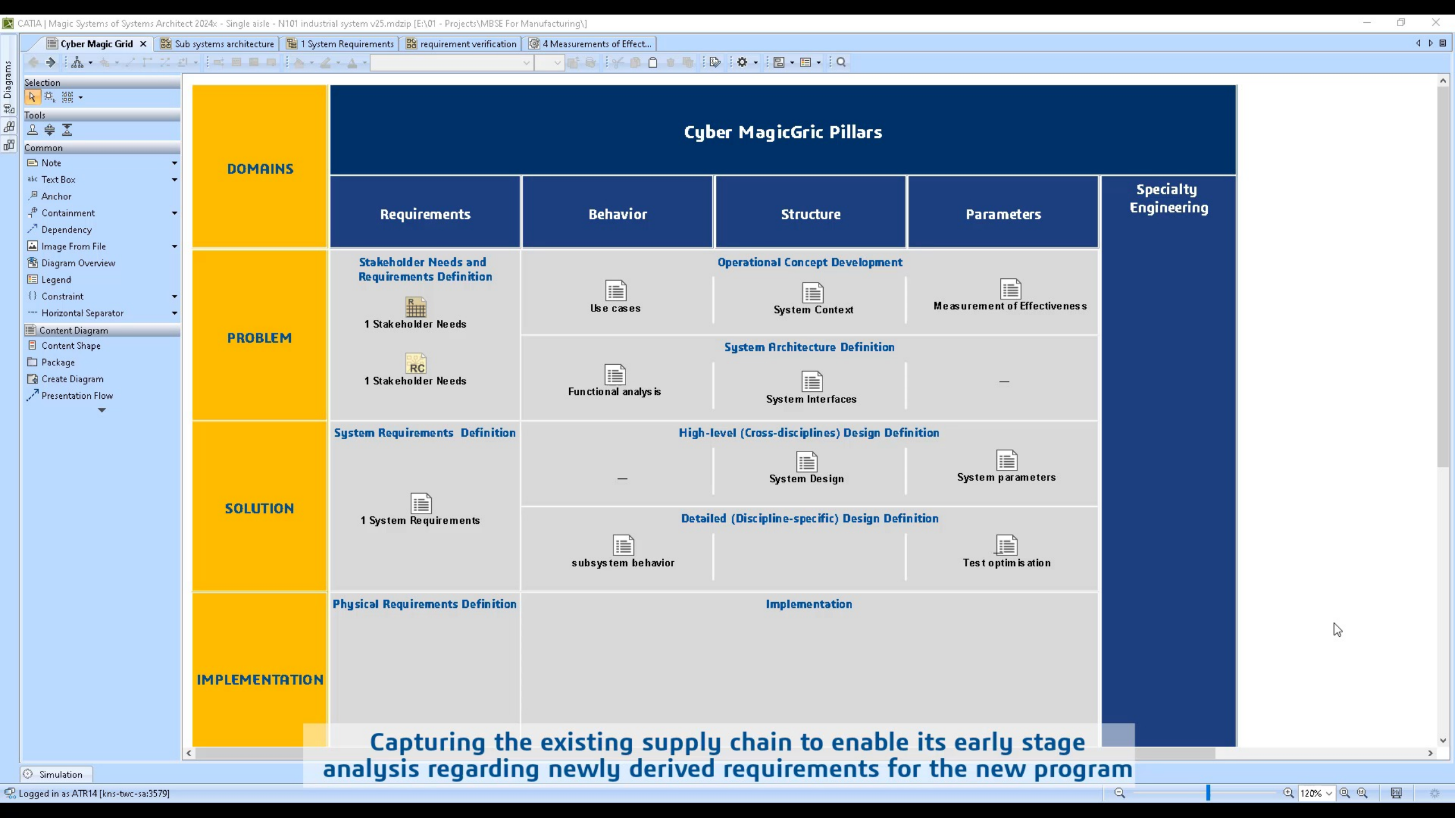
Capturing high-level interactions between different sub-organizations and stakeholders

Deriving Specific Requirements for the Industrial System aligned with the strategical direction

Specifying System Structure and Architecture of the industrial system aligned with the strategical direction

Assess the existing supply chain and production facilities




CATIA | Magic Systems of Systems Architect 2024x - Single aisle - N101 industrial system v25.mdzip [E:\01 - Projects\MBSE For Manufacturing\]
Cyber Magic Grid
Sub systems architecture
1 System Requirements
requirement verification
4 Measurements of Effect...
Selection
Tools
Common
Note
Text Box
Anchor
Containment
Dependency
Image From File
Diagram Overview
Legend
Constraint
Horizontal Separator
Content Diagram
Content Shape
Package
Create Diagram
Presentation Flow
Cyber MagicGric Pillars
DOMAINS
Requirements
Behavior
Structure
Parameters
Specialty Engineering
PROBLEM
Stakeholder Needs and Requirements Definition
1 Stakeholder Needs
1 Stakeholder Needs
Operational Concept Development
Use cases
System Context
Measurement of Effectiveness
System Architecture Definition
Functional analysis
System Interfaces
—
SOLUTION
System Requirements Definition
1 System Requirements
High-level (Cross-disciplines) Design Definition
—
System Design
System parameters
Detailed (Discipline-specific) Design Definition
subsystem behavior
Test optimisation
IMPLEMENTATION
Physical Requirements Definition
Implementation
Capturing the existing supply chain to enable its early stage analysis regarding newly derived requirements for the new program
Simulation
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120%

What Did We See?

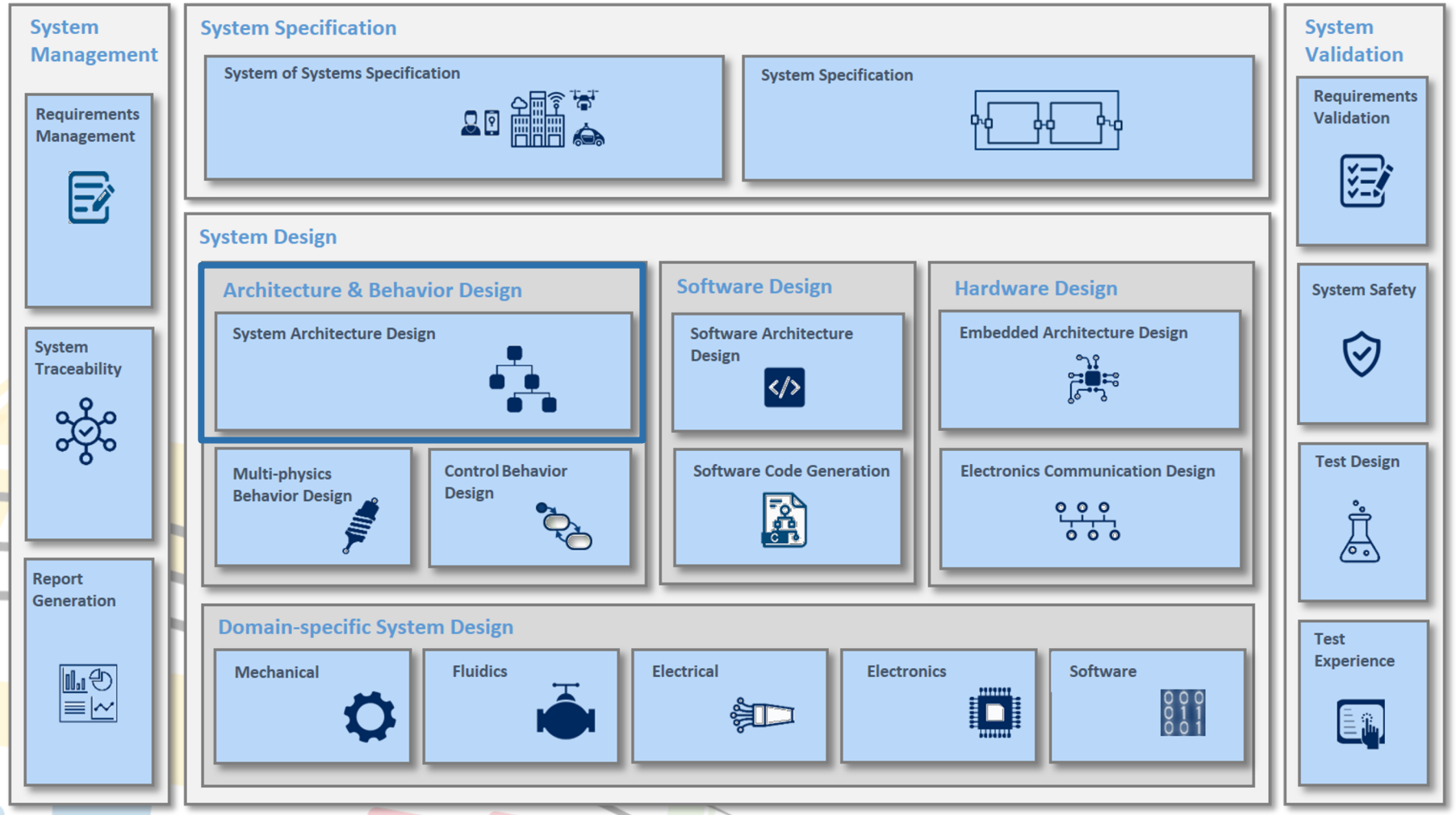
Capturing the supply chain at system level for early stage assessments

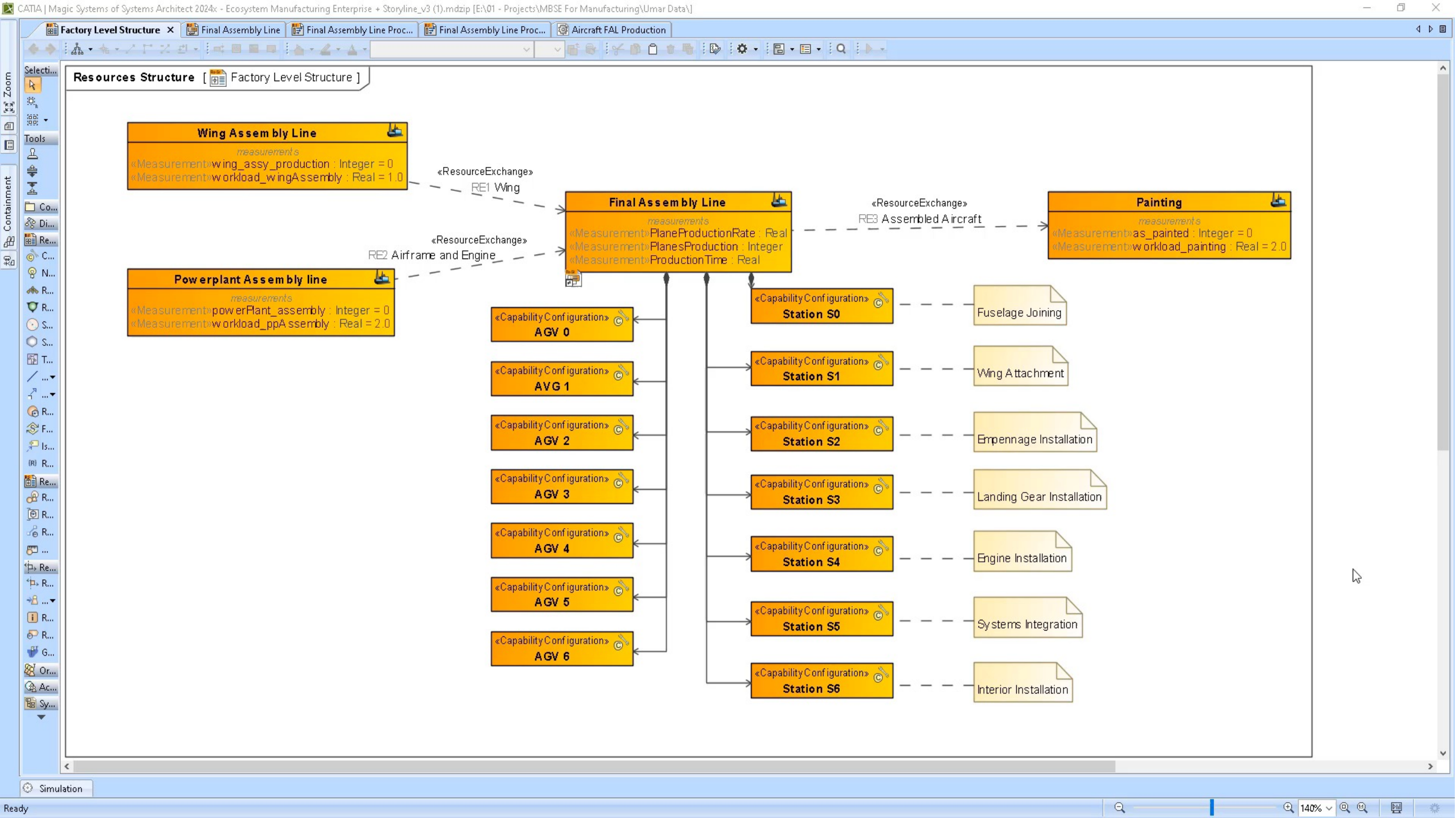
Integrating derived requirements into the industrial system model

Conducting an early producibility analysis for a new program based on the existing supply chain

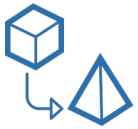
Exploring various supply chain configurations to perform early-stage trade-off analysis

Early performance validation of facilities at plant level




CATIA | Magic Systems of Systems Architect 2024x - Ecosystem Manufacturing Enterprise + Storyline_v3 (1).mdzip [E:\01 - Projects\MBSE For Manufacturing\Umar Data\]
Factory Level Structure
Final Assembly Line
Final Assembly Line Proc...
Final Assembly Line Proc...
Aircraft FAL Production
Resources Structure [Factory Level Structure]
Wing Assembly Line
measurements
«Measurement»wing_assy_production : Integer = 0
«Measurement»workload_wingAssembly : Real = 1.0
«ResourceExchange»
RE1 Wing
Powerplant Assembly line
measurements
«Measurement»powerPlant_assembly : Integer = 0
«Measurement»workload_ppAssembly : Real = 2.0
«ResourceExchange»
RE2 Airframe and Engine
Final Assembly Line
measurements
«Measurement»PlaneProductionRate : Real
«Measurement»PlanesProduction : Integer
«Measurement»ProductionTime : Real
«ResourceExchange»
RE3 Assembled Aircraft
Painting
measurements
«Measurement»as_painted : Integer = 0
«Measurement»workload_painting : Real = 2.0
«CapabilityConfiguration» AGV 0
«CapabilityConfiguration» AVG 1
«CapabilityConfiguration» AGV 2
«CapabilityConfiguration» AGV 3
«CapabilityConfiguration» AGV 4
«CapabilityConfiguration» AGV 5
«CapabilityConfiguration» AGV 6
«CapabilityConfiguration» Station S0
«CapabilityConfiguration» Station S1
«CapabilityConfiguration» Station S2
«CapabilityConfiguration» Station S3
«CapabilityConfiguration» Station S4
«CapabilityConfiguration» Station S5
«CapabilityConfiguration» Station S6
Fuselage Joining
Wing Attachment
Empennage Installation
Landing Gear Installation
Engine Installation
Systems Integration
Interior Installation
Simulation
Ready
140%

What Did We See?



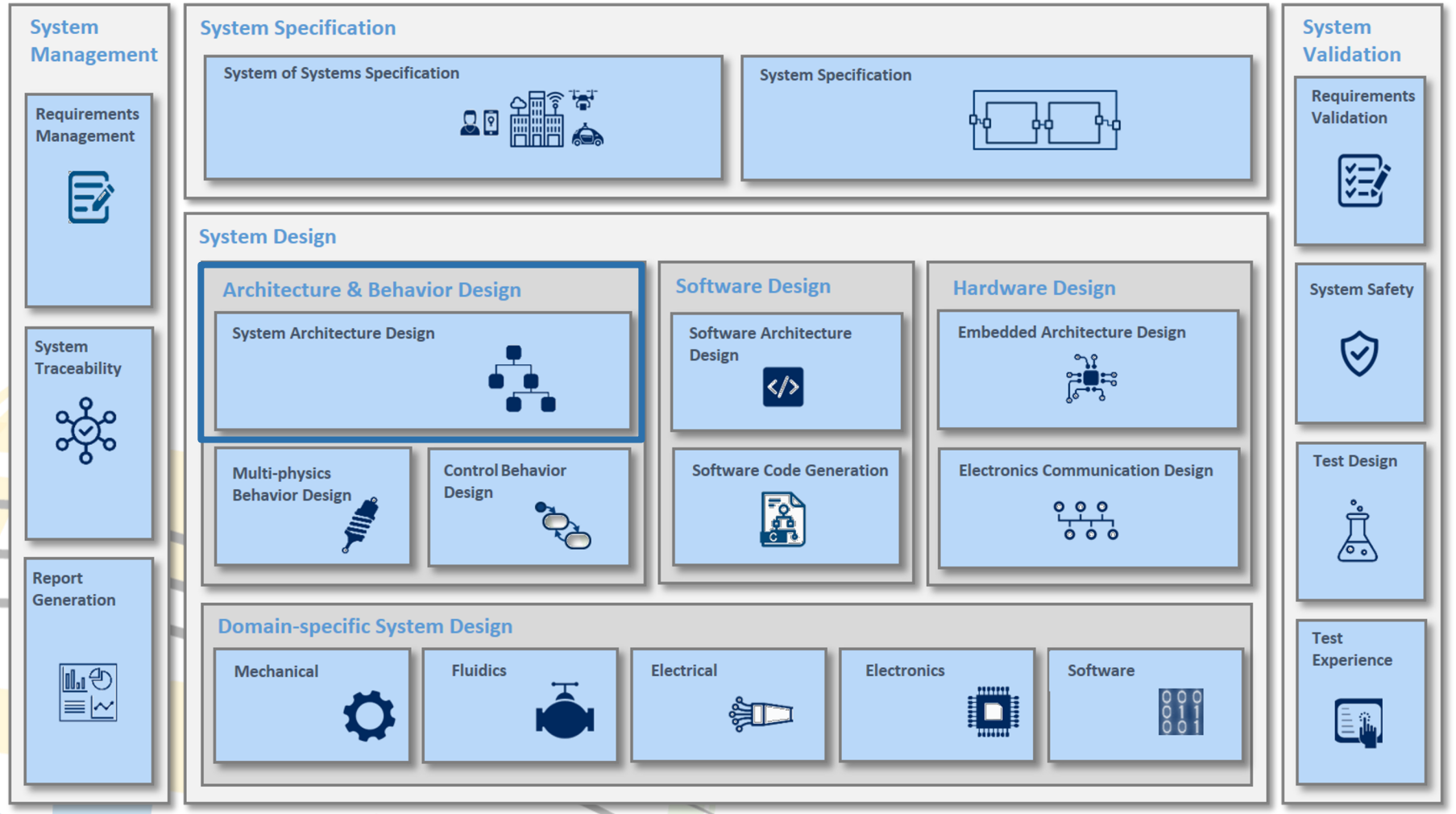
Conducting early analysis at factory plant level to evaluate the impact of equipment changes

High-level behavior modeling of different configurations of the factory plant

Demonstrating how changes at factory plant level will impact the KPIs

Providing high-level understanding and valuable insights to support decision-making at an early stage

Perform early Stage Process Configuration Optimization



Perform early Stage Process Configuration Optimization

Conceptual design

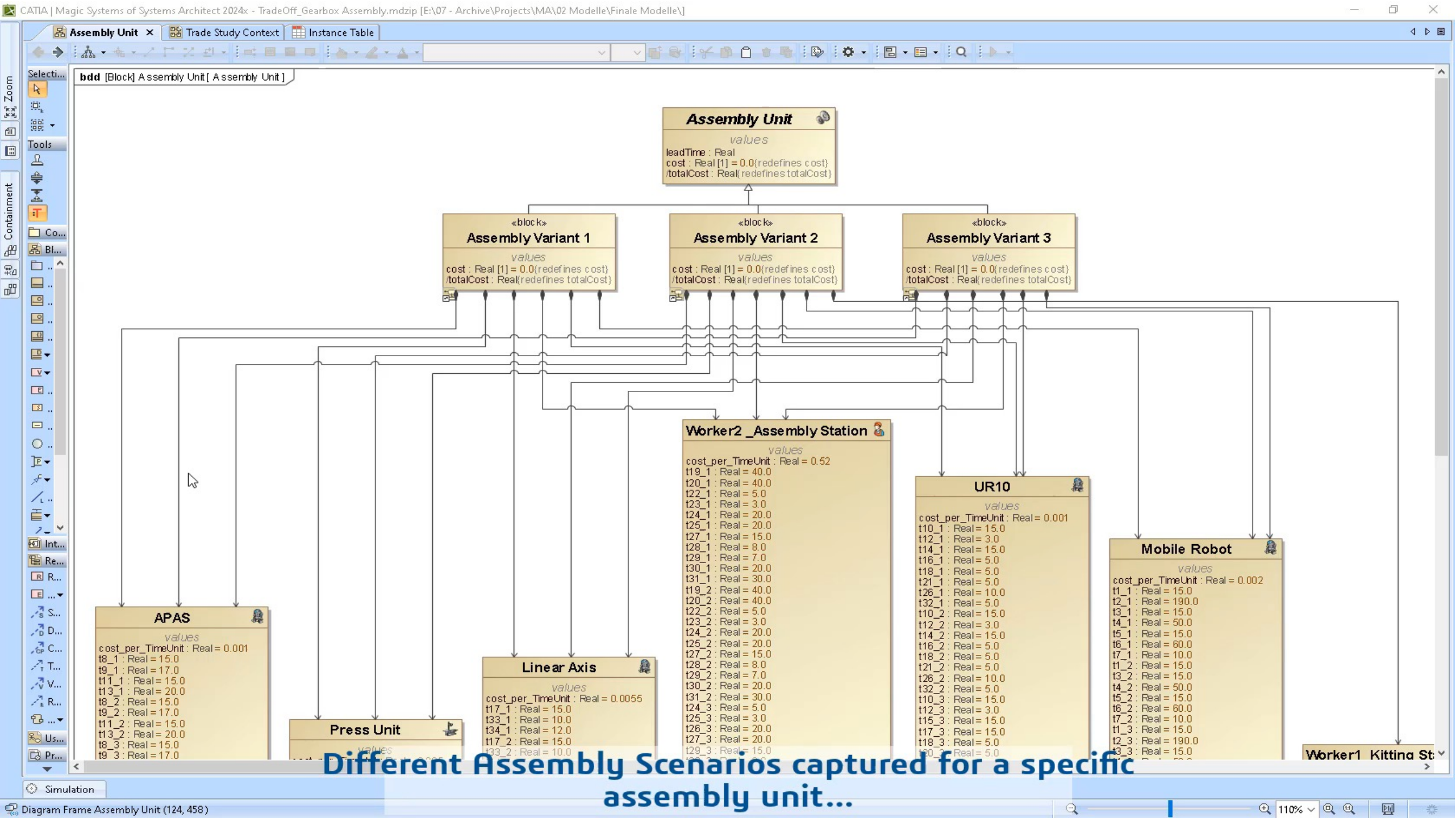
OMG SYSTEMS MODELING LANGUAGE SysML™

System model of the assembly line

Integration of assembly sequences into the system model

CAMEO SIMULATION TOOLKIT™

Simulation and trade-off analyses of the assembly sequences


CATIA | Magic Systems of Systems Architect 2024x - TradeOff_Gearbox Assembly.mdzip [E:\07 - Archive\Projects\MA\02 Modelle\Finale Modelle\]
Assembly Unit
Trade Study Context
Instance Table
bdd [Block] Assembly Unit [Assembly Unit]
Assembly Unit
values
leadTime : Real
cost : Real [1] = 0.0{redefines cost}
/totalCost : Real{redefines totalCost}
«block»
Assembly Variant 1
values
cost : Real [1] = 0.0{redefines cost}
/totalCost : Real{redefines totalCost}
«block»
Assembly Variant 2
values
cost : Real [1] = 0.0{redefines cost}
/totalCost : Real{redefines totalCost}
«block»
Assembly Variant 3
values
cost : Real [1] = 0.0{redefines cost}
/totalCost : Real{redefines totalCost}
Worker2 _Assembly Station
values
cost_per_TimeUnit : Real = 0.52
t19_1 : Real = 40.0
t20_1 : Real = 40.0
t22_1 : Real = 5.0
t23_1 : Real = 3.0
t24_1 : Real = 20.0
t25_1 : Real = 20.0
t27_1 : Real = 15.0
t28_1 : Real = 8.0
t29_1 : Real = 7.0
t30_1 : Real = 20.0
t31_1 : Real = 30.0
t19_2 : Real = 40.0
t20_2 : Real = 40.0
t22_2 : Real = 5.0
t23_2 : Real = 3.0
t24_2 : Real = 20.0
t25_2 : Real = 20.0
t27_2 : Real = 15.0
t28_2 : Real = 8.0
t29_2 : Real = 7.0
t30_2 : Real = 20.0
t31_2 : Real = 30.0
t24_3 : Real = 5.0
t25_3 : Real = 3.0
t26_3 : Real = 20.0
t27_3 : Real = 20.0
UR10
values
cost_per_TimeUnit : Real = 0.001
t10_1 : Real = 15.0
t12_1 : Real = 3.0
t14_1 : Real = 15.0
t16_1 : Real = 5.0
t18_1 : Real = 5.0
t21_1 : Real = 5.0
t26_1 : Real = 10.0
t32_1 : Real = 5.0
t10_2 : Real = 15.0
t12_2 : Real = 3.0
t14_2 : Real = 15.0
t16_2 : Real = 5.0
t18_2 : Real = 5.0
t21_2 : Real = 5.0
t26_2 : Real = 10.0
t32_2 : Real = 5.0
t10_3 : Real = 15.0
t12_3 : Real = 3.0
t15_3 : Real = 15.0
t17_3 : Real = 15.0
t18_3 : Real = 5.0
Mobile Robot
values
cost_per_TimeUnit : Real = 0.002
t1_1 : Real = 15.0
t2_1 : Real = 190.0
t3_1 : Real = 15.0
t4_1 : Real = 50.0
t5_1 : Real = 15.0
t6_1 : Real = 60.0
t7_1 : Real = 10.0
t1_2 : Real = 15.0
t3_2 : Real = 15.0
t4_2 : Real = 50.0
t5_2 : Real = 15.0
t6_2 : Real = 60.0
t7_2 : Real = 10.0
t1_3 : Real = 15.0
t2_3 : Real = 190.0
t3_3 : Real = 15.0
APAS
values
cost_per_TimeUnit : Real = 0.001
t8_1 : Real = 15.0
t9_1 : Real = 17.0
t11_1 : Real = 15.0
t13_1 : Real = 20.0
t8_2 : Real = 15.0
t9_2 : Real = 17.0
t11_2 : Real = 15.0
t13_2 : Real = 20.0
t8_3 : Real = 15.0
t9_3 : Real = 17.0
Linear Axis
values
cost_per_TimeUnit : Real = 0.0055
t17_1 : Real = 15.0
t33_1 : Real = 10.0
t34_1 : Real = 12.0
t17_2 : Real = 15.0
Press Unit
Worker1 Kitting St
Different Assembly Scenarios captured for a specific assembly unit...
Simulation
Diagram Frame Assembly Unit (124, 458)
110%

Perform early Stage Process Configuration Optimization

Conceptual design

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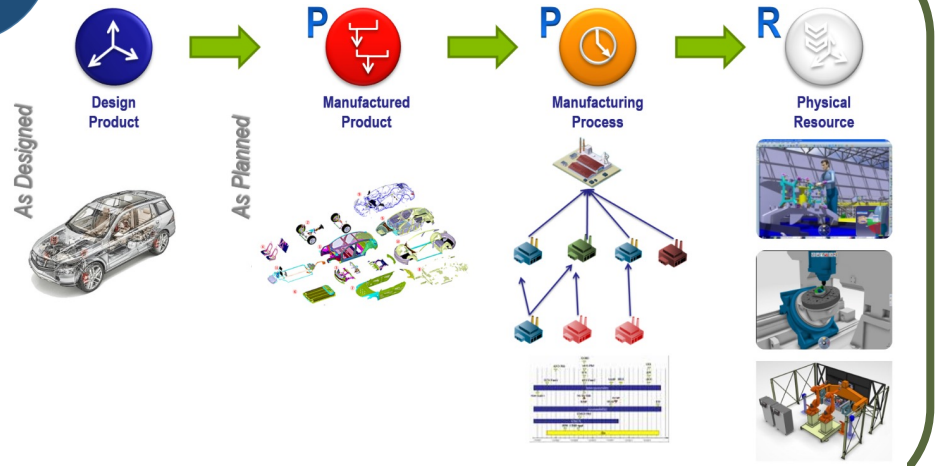
Enterprise Knowledge Language (EKL)

Analysis



System model of the assembly line

Integration of assembly sequences into the system model

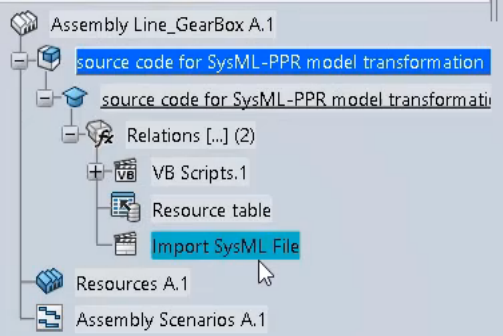
CAMEO SIMULATION TOOLKIT™

Simulation and trade-off analyses of the assembly sequences

Process planning

Ergonomic evaluation

Feasibility evaluation


Assembly Line_GearBox A.1
source code for SysML-PPR model transformation
source code for SysML-PPR model transformati
Relations [...] (2)
VB Scripts.1
Resource table
Import SysML File
Resources A.1
Assembly Scenarios A.1

What Did We See?

Capturing different process configurations at an early stage

Enabling early identification and elimination of suboptimal configurations through trade-off analysis at process level

SysML-PPR model transformation without remodeling in CAD/CAM Environment (DELMIA 3DEXPERIENCE)

Enabling manufacturing specific analysis possibilities (e.g. Process Planning, Ergonomic Evaluation, etc.) based on previously defined processes

Take aways

Integrated MBSE approach for industrial systems to ensure strategic alignment

Informed Decision-Making regarding new program justification before launching it

Early-Stage Simulation-Driven Trade-Off Analysis

Set the right requirements for suppliers from the beginning

Conduct on target and on budget producibility analysis of a new program at an early stage

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